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Biological studies of the invasive species *Nemipterus japonicus* (Bloch, 1791) as a Red Sea immigrant into the Mediterranean

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Abstract The rate of fish invasion into the Mediterranean Sea has increased in recent decades; collectively they have significant ecological and economic impacts in the eastern Mediterranean. One of this species is Japanese thread fin bream *Nemipterus japonicus* that gradually get abundance in the Egyptian Mediterranean coast bottom trawl catch.

During 2011, monthly samples of *N. japonicus* caught off Abu Qir area, Alexandria-Egypt, were used to estimate some biological parameters of this immigrant species.

Females were more in abundance than male in the catch deviated to smaller size than male. Spawning season extended from April to November with highest activities in July. Maximum observed age was 3 years for both sexes with no significant difference between their lengths at age. Length-at-age was fitted to the Von Bertalanffy growth models. Present results of the Mediterranean Sea population showed lower biological (e.g. growth and longevity) condition comparing to original indo-pacific population.

Introduction

Invasive species is defined as introduced species that have overcome biotic and abiotic barriers, and are able to disseminate away from their area of initial introduction through the production of fertile offspring with noticeable impact (Zeneto et al., 2005).The invasion of alien or exotic species in the Mediterranean Sea has been recorded for many years. Since the Suez Canal opening, the Mediterranean Sea has been connected to the Red Sea, and allowed a massive invasion of tropical fauna to the mostly eastern Mediterranean Sea. Several Indo-Pacific species (lessepsian migrants) have entered and started to grow up in the Mediterranean Sea (Öztürk, 2010). In general, however, the impact of most invasive species remains unknown, and the predictability of their direct and indirect effects remains uncertain (Ruiz et al., 1997).

Several immigrants have now become common in local fish landings and markets of Egypt. In the Egyptian waters, the reported impact of immigrant fish species is based on

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assumptions while the benefits are largely economic. In certain cases there is no evidence of measurable conflict (Halim and Rizkalla, 2011).

Japanese thread fin bream, *Nemipterus japonicus* is a demersal species and widespread in the Red Sea and eastern shores of Africa to the Philippines and Japan (Russell, 1993). It is one of the important species commercially caching from Gulf of Suez-Red Sea Egypt. A specimen of the Japanese thread fin bream *N. japonicus* was recorded for the first time from the Mediterranean Sea by Fisher and Whitehead (1974) and then Golani and Sonin (2006). In the last few years, thread fin bream has become one of the demersal finfish resources exploited along the Egyptian Mediterranean coast. They are caught by trawlers up to a depth of 100 m. The catch ratio of *N. japonicus* has been increased within last decade and become as one of the main commercial species.

Biology of *N. japonicus* has been studied by various authors in different regions e.g. Bakhsh (1996) in Saudia Arabia, Rajkumar et al. (2003), Manojkumar (2004), Kerdgari et al. (2009) and many others in India, Amine (2012) in Red Sea Egypt. However, there is no information available regarding the biology of this species in the Egyptian Mediterranean Waters.

The present study aims to present the basic biological parameters of the thread fin bream *N. japonicus* which colonized in the Egyptian Mediterranean Coast.

Materials and methods

The samples of *N. japonicus* were collected two times monthly during the period from February 2011 to January 2012. A total of 703 specimens (394 females, 305 males and 4 undetermined sexes) were caught by bottom trawlers. Sampling sites were restricted to depths of 10–100 m in the northern Abu Qir Bay, Alexandria, Egypt (Fig. 1).

Total Length (TL), Fork length (FL), body weight (W) and gutted weight (GdW) were measured to the nearest millimeter

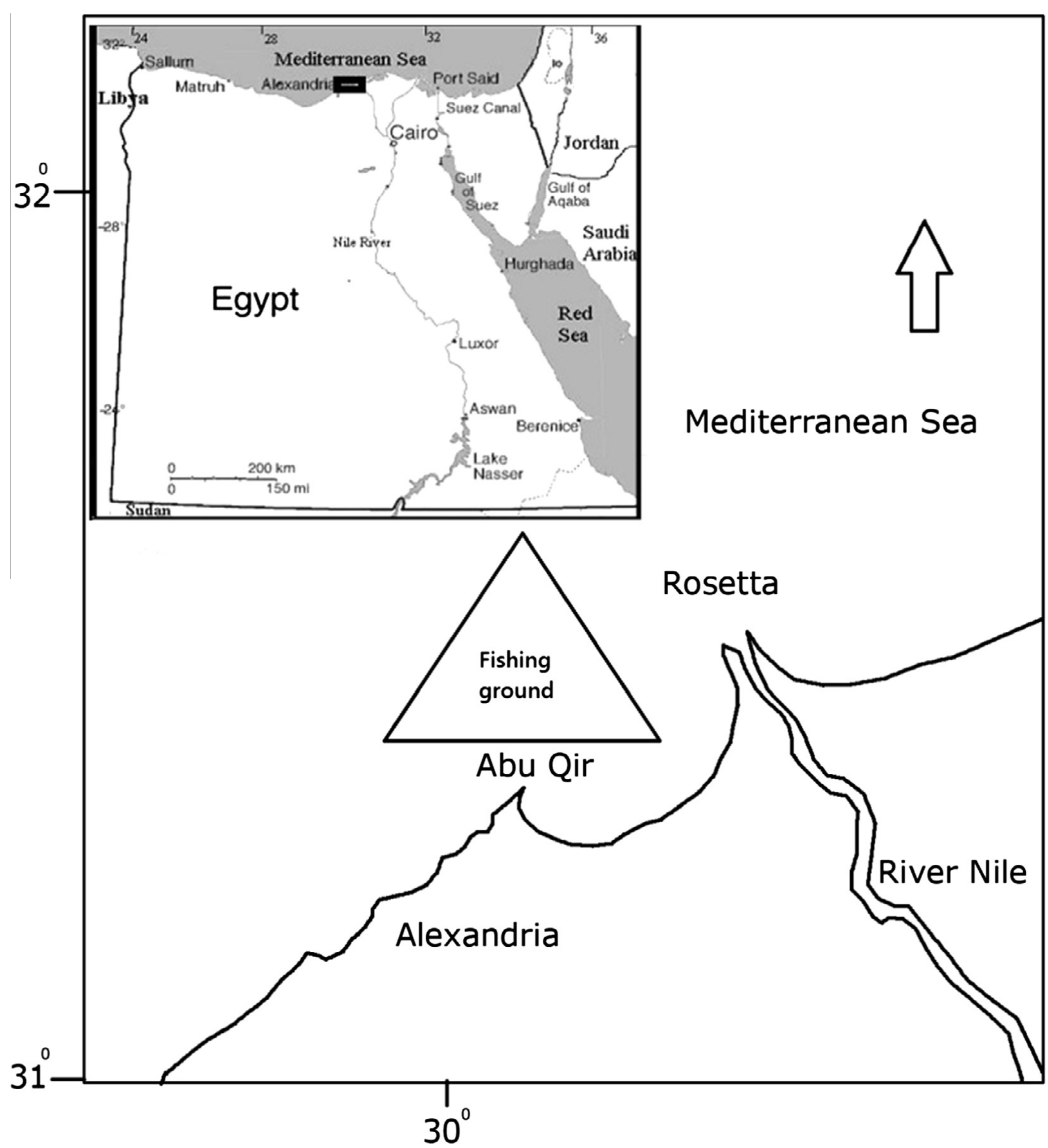

Figure 1 Fishing ground of *Nemipterus japonicus* off AbuQir Bay-Alexandria, Egypt.

and gram for every fish sampled. Sex was checked by the naked eye and gonads were classified to six stages of maturation according to morphological changes that take place during its development to reach spawning (Nikolsky, 1963). Maturity stages were classified as: immature, resting stage, maturing, mature, ripe and spent. Gonadsweight (GW) was measured to the nearest 0.01 g.

Sex ratio was estimated as the number of females to the number of male in the catch.

For detecting the spawning season, Gonad-Somatic Index (GSI) was calculated as follows:

$$\mathrm{GSI} = (\mathrm{GW}/\mathrm{GdW}) * 100$$

The relationship between Body Weight (W) and total Length (TL) was described as:

$W = a{\cdot}L^b$ (Le-Cren, 1951)
Where: a = Intercept and b = Slope

Age determination

Based on preliminary observations of both scales and otoliths (sagittae), otoliths were used for age determination where it revealed clear ring marks. Otoliths of 437 fish were checked. The sagittal otoliths were read whole, against a black background and immersed in glycerol, using a stereo micro-scope.

Distances from the focus to the outer edge of each opaque zone (ring radius, r_n) and to the periphery of the otolith (otolith radius, R) were measured.

The marginal growth increment (MGI) was used to establish the period of ring formation. It is expressed by the following equation:

$$\mathrm{MGI} = (R - r_n)/(r_n - r_{n-1})$$

Relationship between fork length FL in cm and vertebra radius R measured in micrometer division was expressed by linear regression as:

$$\mathrm{FL} = a + bR$$

Where: a and b are constants.

The intercept (a) of the previous relation was used for correction of back calculated fish length (Ln) at year (n) of life using the measured total vertebra radius (R) at annulus radius (rn) by Lee's formula (Lee, 1920): $Ln = (rn(L - a)/R) + a$

A total of 703 fishes with length range 9–23 cm (TL) were used to presume the number of age classes in the available length-frequency data identified by the Bhattacharya (1967)method as subroutine in the FiSAT software (Gayanilo et al., 1995).

Von Bertalanffy growth curve (Pauly, 1983) was then fitted to the available sets of data:

$$L_t = L_{oo}(1 - e^{-K(t-t0)})$$

Where L_t (mm) is the total length at age t (years), L_{oo} (mm) is the asymptotic length, K is the growth coefficient, and t_o (year) is the hypothetical age when the length was zero.

The von Bertalanffy growth parameters, (L_∞ and K), were obtained using Ford-Walford plot (Walford, 1946) as well as FiSAT software (Gayanilo et al., 1995).

The theoretical age at length zero (t_0) was estimated using Pauly's empirical equation (1979): $\mathrm{Log}(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$

Results

Japanese thread fin bream or *N. japonicus* (Bloch, 1791) has an elongated compressed pinkish color body, moderately deep, with eleven to twelve pale golden-yellow stripes along the body from behind the head to the base of caudal fin and prominent red-suffused yellow blotch below origin of lateral line. A single continuous dorsal fin is present and pectoral finis long, reaching just beyond level of origin of anal fin (Fig. 2). Gill rakers were counted and found to range from 12 to 15.

Spawning season

Monthly changing was observed in sex ratio. Females were more abundant in the catch all over the year by different

Figure 2 Thread fin bream *Nemipterus japonicus* (Bloch, 1791)of Abu Qir area, Alexandria, Egypt.

Table 1 Monthly female to male ratio of *Nemipterus japonicus* catch off AbuQir-Alexandria, Egypt during 2011.

Month	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Total
Ratio	1.46	2.58	0.71	1.3	1.3	0.86	1.38	1.24	1.42	0.89	1.31	1.65	1.29

percentage; however they are less abundant in few months like April (Table 1).

Ripe fishes with maturity stage IV were observed from April to November with highest abundance during July. Figure 3 shows the monthly changes in gonadosomatic index (GSI) by sex. For females, GSI started to increase from April, and maintained in high values up to November, then dropped in December. Therefore, the spawning season was considered to be from May to November, with a peak occurring during July. For male, GSI showed almost stable condition all over the year.

Length–Weight Relationships

703 fish with total length (TL) ranging from 9.9 to 23.2 cm and total weights (W) from 12 to 133 g were used to establish their relationships. *t*-Test analysis showed that the female and male TL–W relationship is insignificant ($P > 0.05$). Therefore, all the data were pooled and a common relationship was obtained for all sampled fishes including the undetermined sex specimens.

Length weight relationships for female, male and all samples (as shown in Fig. 4f, m, a) were estimated as:

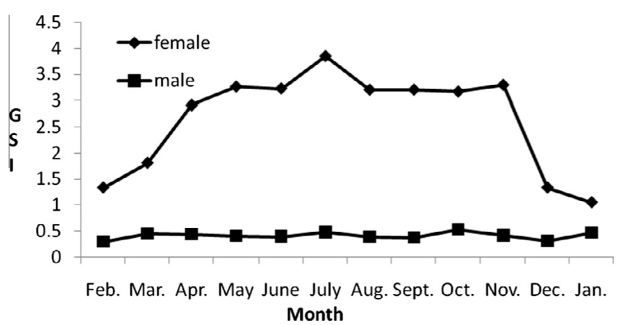

Figure 3 Monthly variation of Gonado-Somatic index (*GSI*) by sex of *Nemipterus japonicus* off AbuQir- Alexandria, Egypt during 2011.

For female $W = 0.0089\text{TL}^{3.1205}(R^2 = 0.9686,\ n = 394)$
For male $W = 0.0121\text{TL}^{2.9966}\ (R^2 = 0.9805,\ n = 305)$
For all sample $W = 0.0113\text{TL}^{3.0266}\ (R^2 = 0.9752,\ n = 703)$

While total length and fork length relationship (Fig. 4TL–FL) was expressed as:

$$\text{FL} = 0.8629TL + 0.3069(R^2 = 0.9734)$$

Age determination

A total of 437 otoliths were used for age determination. Clear ring marks were measured and used for the following growth analysis.

In order to estimate the period of ring mark (outer edge of opaque zone) formation, monthly changes of the marginal growth increment (MGI) were examined by the number of ring marks (i.e. by age group). Fig. 5 shows an appearance of low MGI values in February suggests that new rings were recently

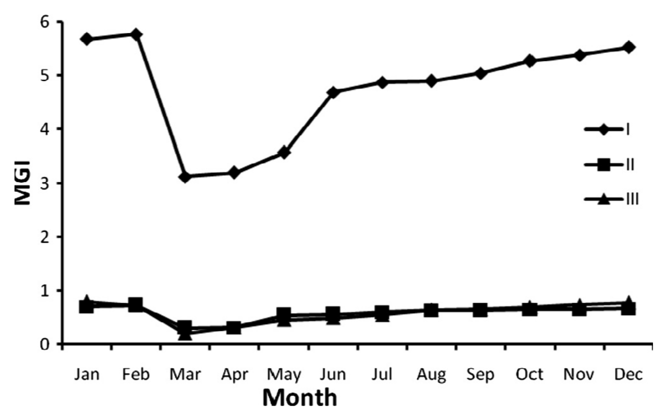

Figure 5 Monthly changes of the marginal growth increment (MGI) for each age group (I, II, III) of *Nemipterus japonicus* off AbuQir-Alexandria, Egypt during 2011.

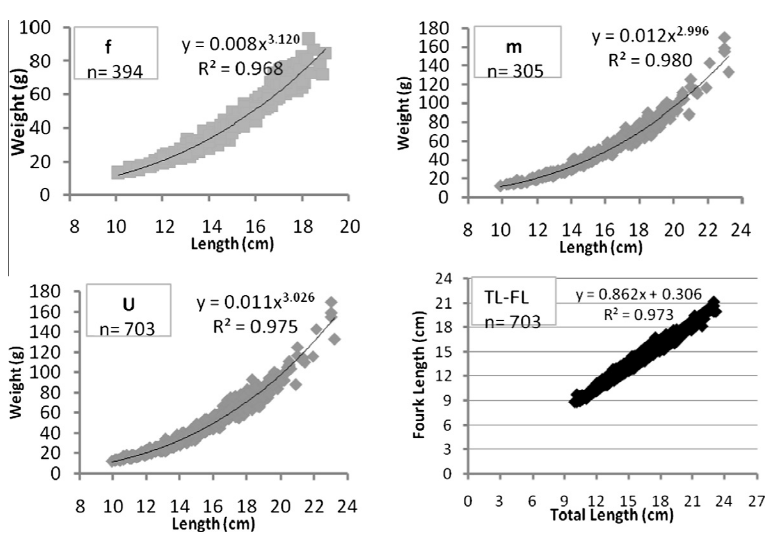

Figure 4 Length–Weight and Length–Length relationships of *Nemipterus japonicus* off AbuQir Bay, Alexandria, Egypt during 2011. (f = Female, m = Male, U = unsexed) while TL–FL is total length-fork length relationship.

Table 2 Mean back calculated lengths (cm) of Otolith reading and from Length Frequency Analysis (LFA) for each sex and all sampled of *Nemipterus japonicus* off AbuQir-Alexandria, Egypt during 2011.

Sex	Number of fish	Age from otolith			Age from LFA		
		I	II	III	I	II	III
Male	184	11.3	15.1	18.0	13.8	16.9	18.8
Female	249	11.7	15.0	17.0	13.2	16.8	–
All fishes	437	11.4	15.0	18.0	13.4	16.6	18.9

completed. Therefore, it is considered as the ring formation time.

Maximum age was found to be 3 years for both sexes and the youngest one was one year.

Total length–otolith radius relationship was estimated for each sex and all sampled fishes after examined the male and female relationships which found to be insignificantly difference ($P > 0.05$). These relationships were represented by the following equations:

Male: $L = 0.5329\ R + 1.3035(n = 184;\ R^2 = 0.9288)$
Female: $L = 0.4193\ R + 1.4888\ (n = 249;\ R^2 = 0.9085)$
All: $L = 0.4926\ R - 0.4753\ (n = 437;\ R^2 = 0.8867)$

Back-calculation method was used for estimated length at age of each sex and all fishes from otolith data as shown in Table 2. The results of otolith data revealed three age groups for both sexes while for length frequency analysis (LFA) suggested the presence of 3 age groups for male and only two age groups (Table 2).

Length and age composition

Length frequency distributions clearly showed differences in sizes range by sexes; both sexes appear in the catch from 10 cm reaching 19 cm for females and 23 cm for males (Fig. 6). The highest length group was 13 cm for female and 17 cm for male.

The age distribution of both sexes of *N. japonicus* indicates that most abundant age groups belong to one and gradually decrease by age. Age group 3 in female was only 1.2% of all observed females in the catch (Table 3).

Growth

The growth curves were fitted to the back calculated length-at-age as follows:

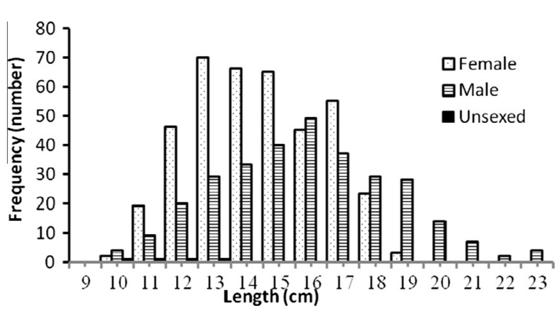

Figure 6 Length frequency distributions of *Nemipterus japonicus* off AbuQir-Alexandria, Egypt during 2011.

Table 3 Age composition (in%) of *Nemipterus japonicas* off AbuQir-Alexandria, Egypt during 2011.

Sex	Age%		
	I	II	III
Male	50	26.1	23.9
Female	61.8	37.0	1.2
All fish	57.2	32.0	10.8

For all fishes $L_t = 33\ (1 - e^{-0.18(t+0.55)})$
For female $L_t = 20.1\ (1 - e^{-0.50(t+1.03)})$
For male $L_t = 27.3\ (1 - e^{-0.27(t+1.55)})$

While for length frequency data of all samples the equation is expressed as:

$$L_t = 34.4(1 - e^{-0.15(t+0.26)})$$

Discussion

The rate of invasive species in the Mediterranean Sea has been increased considerably with time. The disappearance of some physical or chemical barriers opened the way to additional species from the Red Sea to cross the Suez Canal and colonize in the Mediterranean Sea. Some of these alien species that were introduced by way of the Suez Canal were very successful and have established large populations in the eastern Mediterranean. They are regularly captured and constitute an important share of commercial catches with economic importance (Bariche, 2010). Some of the alien fish species have become economically important after the establishment of sustainable populations in the eastern Mediterranean region such as lizard fish while other has negative impacts on human health like *Legocephalus* sp. Thread fin bream (Family Nemipteridae) is one of these species that become an important demersal resources caught throughout the year in small trawlers along the Egyptian Mediterranean coast. The first record of a nemipterid fish species in the Mediterranean Sea was reported by Fisher and Whitehead (1974) as a Red Sea immigrant *N. japonicus* (Bloch, 1791) followed by Golani and Sonin (2006). However, Lelli et al. (2008) concluded that their specimen is a misidentification of *N. randalli*, and previous reports of *N. japonicus* from the Mediterranean Sea including unconfirmed records and can be referred to *N. randalli*. Most of the features of both species are similar with few differences in characters. In the present study following Russell (1990) identification characters, the present samples are *N. japonicas* with eleven to twelve pale golden-yellow stripes along body from behind head to the base of caudal fin and 12 to 15 Gill rakers.

The significance of alien species in marine ecosystems worldwide has been highlighted in recent years. International organizations (UNEP/MAP/RAC/SPA, FAO/DIAS, IUCN, ICES, IMO, CIESM) and the scientific community have addressed the issue through articles, review papers, databases and directories (Zeneto et al., 2005). Halim and Rizkalla (2011) mentioned that while the invasive species are beneficial to local fisheries, they do not have an important impact upon the ecosystem. Elsewhere, nemipterid species are an important component of artisanal and commercial fisheries (Russell, 1990) and the recently established population in the Eastern Mediterranean may well in future form the basis of an important fishery in the area. Impacts of the alien species should be considered also for the fisheries management.

During the period of the present study females were more abundant in the catch of *N. japonicus* in most of the months. Bakhsh (1996) found that females dominated the catch from the Jizan Region of Red Sea while Amine (2012) observed that M:F ratio is 1:1.2 in the Suez Gulf-Red Sea. Kerdgari et al. (2009) found that in Northern Persian Gulf females predominated the catch (M:F ratio was 1:2.6). Some studies in different regions in India concluded that sex ratio was slightly deviated from the expected ratio of 1:1 showing domination of females in the commercial catches (Manojkumar, 2004 and Kizhakudan et al., 2008), while others (Murty, 1984 and Raje, 2002) observed that males outnumbered females in all months except only few months over the year.

In the present study, ripe fishes (stage IV) were observed from late April to November with the highest GSI in July, indicating a prolonged spawning season with one peak at warming months of the year in Egypt. *N. japonicus* in the Gulf of Suez had prolonged spawning season extending from September to February and from May to July (Amine, 2012). Earlier studies have indicated that peak spawning was during September–April off Indian Coast (Raje (2002), Manojkumar (2004) and Kizhakudan et al. (2008)). Spawning activity of the thread fin bream populations along the Indian Ocean coast has a major peak during the post monsoon months from September to December. Bakhsh (1996) concluded that threadfin breams spawn over extended periods varies from one region to another according to some factors such as wind, current and not directly to temperature.

In the present study no significance difference was found in length weight relationship by sexes. The b factor of the relation was almost 3 referred to symmetrical or isometric growth. Vivekanandan and James (1986) for Madras waters in India,Mathews and Samuel (1991) for Kuwait waters, Manojkumar (2004) for north west coast of India, Kerdgari et al. (2009) for Northern Persian Gulf and Pawar et al. (2011) of Goa stat-India populations found b value more close to that presented for both sexes and pooling data in the present study. Differences in Length weight relationship by sexes and regions are very clear among the previous study for *N. japonicus*. Bakhsh (1996) for the Jizan Region of Red Sea and for Karnataka region in India (Zacharia, 1998), Kizhakudan et al. (2008) and Suresh Kumar et al. (2011) in India, Amine (2012) in Suez Gulf-Red Sea and Afshari et al. (2013) in the Northern Oman Sea estimated b value less than the present study (b value between 2.6 and 2.8). A number of factors are known to influence length-weight relationships in fishes, including growth phase, season effect, size range, general fish condition and size selectivity of the sampling gear (Tesch, 1971).

Annual rings were found in the otoliths and were validated by evolution of the marginal otolith increments. Only three age groups were detected. Otolith is one of the most suitable options for age determination of tropical and subtropical marine fishes (Green et al., 2009). Afshari et al. (2013) used otolith section and reported one to five age groups for thread fin bream in Oman Sea. Moreover, in the present study age was determined based on length frequency analysis as most of the previous age studies of thread fin breams all over the world. Three age groups were identified for male while only two for female. For both sexes together, the first age group was 13.4 and the second 16.6 cm while the third was 18.9 cm. Krishnamurthi (1971) had observed *N. japonicus* off Visakhapatnam attaining 15, 21 and 24 cm at the end of 1, 2 and 3 years, respectively. Murty (1984) had reported the lengths as 18.5, 25.5 and 28.5 cm for the corresponding ages from Kakinada area in India, while Amine (2012) stated that mean lengths of Suez Gulf population were 12.65, 16.46, 19.90, 23.72 and 26.99 cm, for the recorded five groups respectively. The first three mean lengths per years are closed to the present estimates. Studies of Granada et al. (2004) showed that species of *Nemipterus* genus cannot survive more than 10 years and females are with the lower longevity than males that confirms the results of the present study. The longevity of fish species might be affected by the environmental conditions under which a fish lives (Wootton, 1990). Clarke (1983) stated that the higher growth rate in males has been attributed to less energy diverted/required for reproduction and production of gametes in males compared to females resulting in higher somatic growth in males.

Age group one was dominated in the present study catch, while Afshari et al. (2013) reported that the most abundant age groups belong to age groups of 3–4 years old and the least one was determined for age groups of 1–2 years old. Kizhakudan et al. (2008) describe the catch of *N. japonicus* comprised of wider length range of 6–39 cm. Such differences may belong to fishing gear selectively mainly. Length composition of the present study was deviated to smaller fishes confirms that finding.

The difference in growth of males and females of *N. japonicus* observed in the present study can be compared with the earlier studies which reported differential growth with males attaining larger length than females in Indian Coast (Eggleston, 1972; Krishnamurthi, 1976; Amornchairojkul and Boonwanich, 1982; Murty, 1984),and in seas off Kuwait (Mathews and Samuel, 1991).

Von-Bertalanffy growth model (Von-Bertalanffy, 1938) is one of the most commonly used methods in studying theoretical growth in fishery's biology. The estimated growth parameters by earlier workers along the east coast of India using different methods shows that the values of (L_{oo}) ranged from 23.5 to 38.2 cm and K from 0.40 to 1.00 yr^{-1}(Rajkumar et al., 2003 and Joshi, 2010). For the Red Sea population and (K) were 33 cm and 0.45 yr^{-1} respectively (Amine, 2012). In Hong Kong early study by Lee (1975) on *N. japonicus* estimated L_{oo} as 34.1 cm and K as .19 yr^{-1}. The present estimates are within the above range for (L_{oo}), while estimate of (K) is less for polled sexes data in India and Red Sea but closed to in Chain Sea. The growth pattern of *N. japonicus* from the

Egyptian Mediterranean coast appears to have less growth rate among other populations inhabiting Indian Ocean and Red Sea but similar to that inhabiting Chain Sea with similar environmental parameters.

It can be concluded that *N. japonicus* from the Egyptian Mediterranean coast is in a lower biological condition (e.g. growth and longevity) than the original population in Indian Ocean but has some similarities with that of the Red Sea and China Sea.

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